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THE SPAWNING AND FECUNDITY OF THE WHITE CROAKER *ARGYROSOMUS MACROCEPHALUS* (TANG)

FAH-HSUEN LIU[1] AND IH-HSEU TUNG[2]

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The white croaker is one of the important products of trawl fisheries of Taiwan and its amount of catch ranges next to that of the lizard fish (1). Thus far four species have been found to exist around this Island: *Argyrosomus macrocephalus* (Tang), *A. argentatus* (Houttuyn), *A. pawak* Lin and *Johnius carutta* Block. Figures of catch were not classified according to species before 1959. *A. macrocephalus* (Tang) is the most important species with regard to the annual production.

Available information on the white croaker is rather scanty (2, 3, 4, 5). The three species of *Argyrosomus* have a different pattern of distribution: *A. argentatus* inhabits mainly the region north of 28°N, *A. macrocephalus* between 22°N and 28°N, while *A. pawak* is limited to south of 22°N (4). *A. macrocephalus* is found only in the Strait of Taiwan (5). Moreover, the local catch of the white croaker is mainly composed of *A. macrocephalus*. *A. argentatus* are very few, for this reason the local people call the former, the Taiwan white croaker and the latter, the Japanese white croaker. Former work of both Kasahara (2) and Saishu (3) dealt chiefly with *A. argentatus*. Since knowledge on *A. macrocephalus* remains obscure for the most part, the authors made a comprehensive study on the spawning and fecundity of this species in order to better understand its recruitment.

MATERIALS AND METHODS

The fishing data used for analysis were secured from the log books of six pairs of bull trawlers of the former Taiwan Fisheries Corporation. Random fish samplings were obtained from the market from June 1958 to July 1959. The methods used in this study are described separately under different topics in the text, for the purpose of clarity.

The Spawning Time

The spawning time is determined jointly by 3 methods: 1) gross observation of the gonadal conditions, 2) study of the index of maturation and 3) observation of the development of the ovarian eggs.

1) *Gross observation of the gonadal conditions.* The gonad of this fish can be divided into 4 stages as follows:

Female:
- A. Immature. Ovary slender and transparent, without eggs.
- B. Premature. Ovary large, with a few yellow yolked eggs.
- C. Mature. Bulging ovary full of yellow yolked eggs, with some transparent, large blood vessels on the surface clearly discernible.
- D. Spent. Ovary loose and spongy, a few yellow and transparent eggs left.

Male:
- A. Immature. Testis slender and thread like.
- B. Premature. Testis large, white, no milt can be pressed out.
- C. Mature. Testis large, solid and white, milt can be easily pressed out.
- D. Spent. Testis loose.

Samples were taken and examined monthly, and the result is recorded in Table I. Although some of the class B females might have been erroneously identified as class C, due to difficulties of

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[1] Professor, Department of Zoology, National Taiwan University and research fellow, Institute of Zoology, Academia Sinica.

[2] Junior researcher, Institute of Fishery Biology.

TABLE I

*Gonadal maturity recordings of A. macrocephalus**

Maturity \ Month			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Ovary	Immature	No.	16	5	17	14	7	0	0	0	0	22	9	6
		%	76	83	89	67	20	0	0	0	0	61	75	86
	Premature	No.	5	1	2	7	11	10	1	6	4	6	1	1
		%	24	17	11	33	31	71	10	100	67	17	8	14
	Mature	No.	0	0	0	0	17	3	6	0	0	0	0	0
		%	0	0	0	0	49	22	60	0	0	0	0	0
	Spent	No.	0	0	0	0	0	1	3	0	2	8	2	0
		%	0	0	0	0	0	7	30	0	33	22	17	0
	Sum	No.	21	6	19	21	35	14	10	6	6	36	12	7
		%	100	100	100	100	100	100	100	100	100	100	100	100
Testis	Immature	No.	9	2	16	9	5	0	1	0	2	1	5	3
		%	90	67	70	41	13	0	9	0	11	5	26	75
	Premature	No.	1	1	7	13	23	10	2	5	17	13	2	1
		%	10	33	30	59	62	59	19	100	89	65	11	25
	Mature	No.	0	0	0	0	8	5	4	0	0	4	2	0
		%	0	0	0	0	22	29	36	0	0	20	11	0
	Spent	No.	0	0	0	0	1	2	4	0	0	2	10	0
		%	0	0	0	0	3	12	36	0	0	10	52	0
	Sum	No.	10	3	23	22	37	17	11	5	19	20	19	4
		%	100	100	100	100	100	100	100	100	100	100	100	100

* Minimal length of the fish specimens examined: female, 151 mm; male, 141 mm.

precise differentiation in some cases, the available data indicate that the mature females were found only in May, June and July. Mature males appear chiefly also in these months, but may be found as late as October and November.

2) *Study on the index of maturation.* The index of maturation is expressed by previous workers as the relation between the weight of ovaries and the weight or length of the body. The weight-weight relationship usually fits better than the weight-length relationship as has been shown in many other fishes. It is interesting that this fish shows good relationship in both ways and in all months except August. Table II shows that the values of the regression coefficient and the standard deviation from regression increase after May, being highest in July and August respectively. This is interpreted to mean that the ovary increases in weight gradually during these months, while the weight and length of the body remain constant. These months, therefore, must be the period of maturation.

3) *Observation of the development of the ovarian eggs.* The ovaries of the white croaker, like those of the other teleosts, are composed of two long sacks within which eggs of different stages co-exist even at the time of spawning.

Since different-sized eggs distributed unevenly in the ovary, samples were taken from all the three regions of the ovary for examination. The eggs were measured microscopically only after being fixed in Bouin's solution for at least one week, because in this solution shrinking of egg becomes constant after five days (Fig. 1).

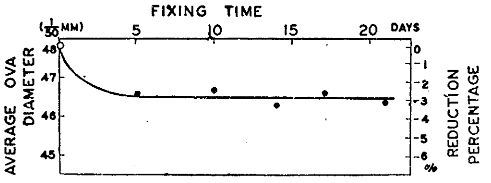

Fig. 1. Reduction of ova diameter owing to fixing by bouin's solution.

The eggs in the immature ovaries were smaller than 0.2 mm in diameter. At this stage, different-sized eggs distributed evenly throughout the A, B, C regions (Fig. 2A). As they developed to the stage when the largest eggs reached 0.56mm in diameter, zonal distribution of the egg according to size was gradually established, *i. e.*, larger eggs tended to accumulate at the lower part of the ovaries in the order A, B, C. Up to this period the eggs were opaque.

TABLE II

Linear relationships between ovary weight and body length, and ovary weight and body weight in A. macrocephalus

Month	OW–SL			OW–BW			No. of Sample
	b	sy•s	$\beta=0$	b	sy•s	$\beta=0$	
Apr.	0.1368	2.83	P <0.01	0.0640	2.91	P <0.01	26
May	0.3642	13.79	P <0.01	0.1675	13.20	P <0.01	32
June	1.0391	27.63	P <0.01	0.4764	26.04	P <0.01	20
July	1.3170	20.67	P =0.014	0.5065	19.49	P <0.01	12
Aug.	1.0993	44.37	P =0.175*	0.4598	43.12	P =0.145*	8
Sept.	0.8112	19.38	P <0.01	0.3820	17.44	P <0.01	19
Oct.	0.1803	3.74	P <0.01	0.0831	3.54	P <0.01	15
Jan.	0.1014	0.30	P <0.01	0.0480	1.79	P <0.01	26
Mar.	0.1552	2.72	P <0.01	0.0820	3.92	P <0.01	24

Legend. OW : Ovary weight.
SL : Standard length.
BW : Body weight.
b : Regression coefficients.
sy.s: Standard deviations from regression.
$\beta=0$: Tests of null hypothesis.
* : No linear relationship.

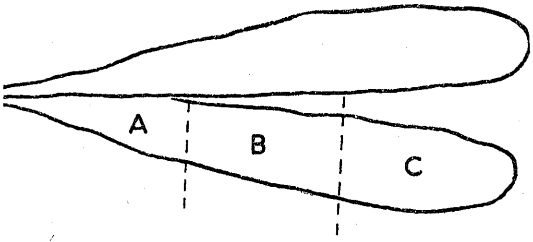

*Fig. 2*A. positions of the ovary where eggs are sampled.

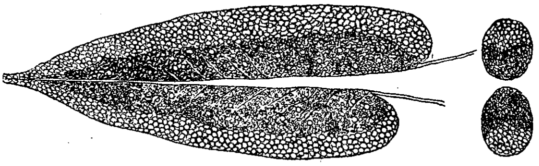

*Fig. 2*B. Mature ovary of white croaker.

The eggs became transparent when they reached 0.64 mm in diameter. Meanwhile oil globules began to appear which started clumping when the eggs reached the size of 0.7–0.8 mm in diameter. Apparantly transition between the opaque eggs and transparent ones was transient, because very few eggs with a size around 0.64 mm were found. When most of the eggs turned transparent the segregation of eggs according to size became all the more obvious, so that eventually, the zone of transparent eggs could be clearly distinguished from that of the opaque ones. Transparent eggs left the lamella when they attained a size of about 0.9 mm in diameter. It was at this stage that two clear-cut regions were observed in the ovary: the region of transparent eggs stood in distinct contrast to that of the opaque ones as shown in Fig. 2B. In the fresh condition the transparent eggs ranged 0.84–1.08 mm with a mean of 0.957±0.0574 mm in diameter, and the mean size of oil globules was 0.222±0.01735 mm.

The spent ovaries were spongy, but many mature eggs still remained, most of which were 0.6 mm in diameter. Zonal distribution of eggs according to size in the spent ovaries was similar to that in the ovaries before spawning. Mature females were at least 15 cm long.

Measurements of the ovarian eggs taken from May to September are plotted in frequency graphs as shown in Fig. 3. It will be noted that the mature eggs, *i. e.*, transparent ones larger than 0.6 mm in diameter, appeared mostly from June to August: This was in agreement with the time deduced by the first method mentioned above.

The spawning time as determined by the three methods agrees satisfactorily with one another. The time of maturation of eggs is determined to be, by different methods, as follows: gonadal analysis, May-July; maturation index, May-August; egg size measurement, June-August. The balance of evidence suggests therefore, that the eggs start maturing in May and are spawned during June-August.

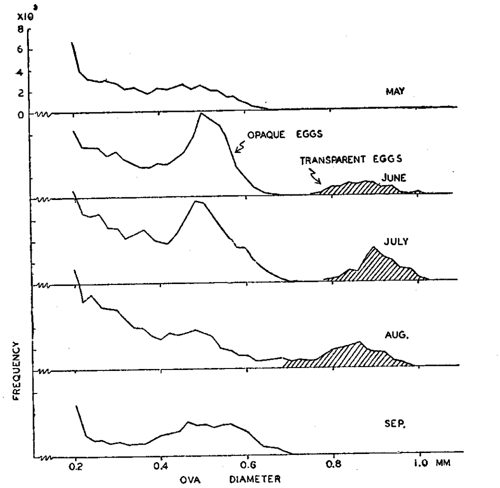

Fig. 3. Frequency charts of the monthly averages of ova diameter.

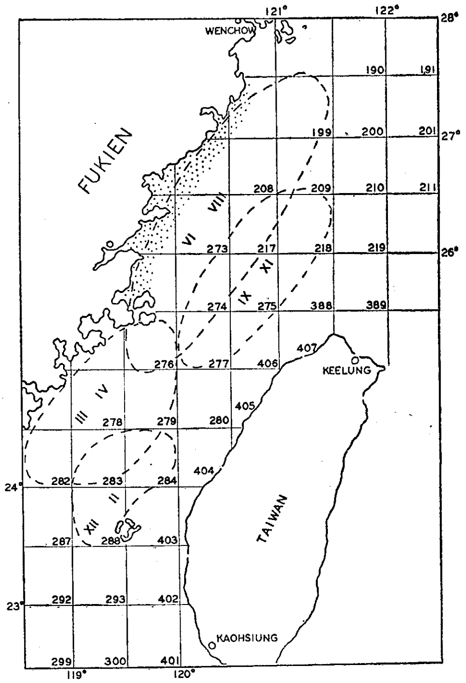

Fig. 4. The fishing ground and the spawning ground of white croaker (*A. Macrocephalus*).
○ fishing ground.
● spawning ground

The Spawning Place

Since the spawning time is determined to be June-August, the spawning ground must be the place where mature specimens are caught during these months. As indicated in Fig. 4, this is encircled by the broken lines carrying the Roman figures VI-VIII (June-August). The actual spawning area, which is dot-marked in the figure, is inferred to be along the sea coast of Fukien between Wenchow and Foochow.

Liu and Tung (4) found that this fish migrates northward toward the coast of mainland China during March-May and southward during July-October. Liu and Chen (5) found that it appears at the southern part of Taiwan Strait in winter, and frequents the north during the summer months. Fig. 4 is constructed on the basis of data collected from six pairs of bull trawlers. The migration tendency described therein agrees well with previous findings. The areas encircled by broken lines show that *A. macrocephalus* passes the winter in the vicinity of Pen Hu. After first migrating toward the coast of mainland China it moves northward after March for the purpose of spawning.

Estimation of the Egg Production Potentialities of Females

The entire egg content of the pair of ovaries of selected mature fish was mixed with 200 ml of water, and after thorough mixing a 2 ml sample was taken with a piston pipette. The number of eggs which measured more than 0.2 mm in diameter was then counted, and the results obtained over one year is given in Table III. From this the relationship between the number of eggs and the ovary weight, and between the number of matured eggs and the body weight or length, can be computed. Fig. 5 is a regression graph for the number of eggs on weight of ovary, and *vice versa*. It is found that these two factors correlate very well, since the correlation coefficient $r=0.948$. Given a known weight of ovary (OW), the number of potentially producible eggs (E) can be computed by the following equation:

$$E=16.504\ OW-0.3481$$

The ovaries that contain transparent eggs are heavier than the weight expected from the equation. This is due to the fact that the eggs measuring 0.2 mm in diameter increase only in

TABLE III.

Ovarian eggs counting record

Fishing date	Collecting date	Standard length, mm	Body weight, g	Ovary weight, g	Number of ovarian eggs (above 0.2mm)
June 1958	June 1958	213	210	5.7	95,500
〃	〃	200	200	6.3	107,600
〃	〃	199	180	10.5	166,600
June 1958	June 1958	212	240	12.0	151,800
〃	〃	202	210	9.1	144,000
〃	〃	198	200	9.0	169,600
〃	〃	177	130	7.7	127,700
〃	〃	167	130	3.1	36,900
〃	〃	171	130	12.3	72,000
〃	〃	169	130	5.5	90,700
〃	〃	168	130	5.5	118,000
〃	〃	165	120	3.0	39,300
〃	〃	163	120	4.8	84,700
〃	〃	153	100	0.6	few
July 1958	July 1958	212	210	8.2	169,900
〃	〃	209	210	9.6	143,700
〃	〃	204	260	8.2	152,000
〃	〃	188	160	9.6	135,900
〃	〃	178	110	2.4	53,000
〃	〃	166	100	4.6	65,600
Aug. 1958	Aug. 1958	203	200	6.3	99,600
〃	〃	196	170	5.3	113,400
Aug. 1958	Aug. 1958	227	250	6.3	124,100
〃	〃	225	250	10.0	129,300
〃	〃	210	220	14.7	227,100
〃	〃	205	200	15.9	100,000
〃	〃	170	110	3.5	25,700
〃	〃	160	90	3.3	30,000
Sept. 1958	Sept. 1958	192	220	6.3	106,800
〃	〃	183	150	2.2	24,200
〃	〃	155	100	0.7	6,500
Sept. 1958	Oct. 1958	178	130	0.7	0
〃	〃	175	130	1.0	32,000
〃	〃	175	110	0.5	0
〃	〃	161	100	0.5	0
Sept. 1958	Oct. 1958	207	220	7.1	102,500
〃	〃	206	200	1.9	15,300
〃	〃	186	160	6.3	87,600
〃	〃	186	150	6.4	118,200
〃	〃	186	150	4.8	78,100
〃	〃	159	100	2.0	28,800
〃	〃	150	90	0.9	7,600
〃	〃	149	80	0.7	700
Oct. 1958	Nov. 1958	176	120	0.9	few
〃	〃	172	110	0.6	0
〃	〃	164	100	0.5	0
〃	〃	163	100	0.7	few
Nov. 1958	Dec. 1958	204	180	0.6	few
〃	〃	193	170	0.8	0
〃	〃	186	150	0.6	0
Apr. 1959	Apr. 1959	209	220	1.9	0
〃	〃	203	200	1.0	0
〃	〃	199	190	1.0	0
〃	〃	194	180	1.1	few
〃	〃	186	180	1.0	0
〃	〃	178	150	1.4	few
Apr. 1959	May 1959	215	220	1.2	0
〃	〃	203	180	1.1	few
〃	〃	185	160	1.2	few
May 1959	May 1959	228	240	4.4	64,700
〃	〃	213	220	5.2	10,000
〃	〃	211	210	3.1	46,600
〃	〃	191	150	2.2	38,800
〃	〃	184	140	2.2	32,900
〃	〃	184	140	1.8	24,700
June 1959	June 1959	204	200	8.2	92,700
〃	〃	177	120	2.8	43,100
〃	〃	176	120	3.6	51,500
〃	〃	175	120	3.1	53,600
July 1959	July 1959	207	210	9.1	175,00
〃	〃	199	170	4.2	127,00
〃	〃	192	170	4.0	58,000

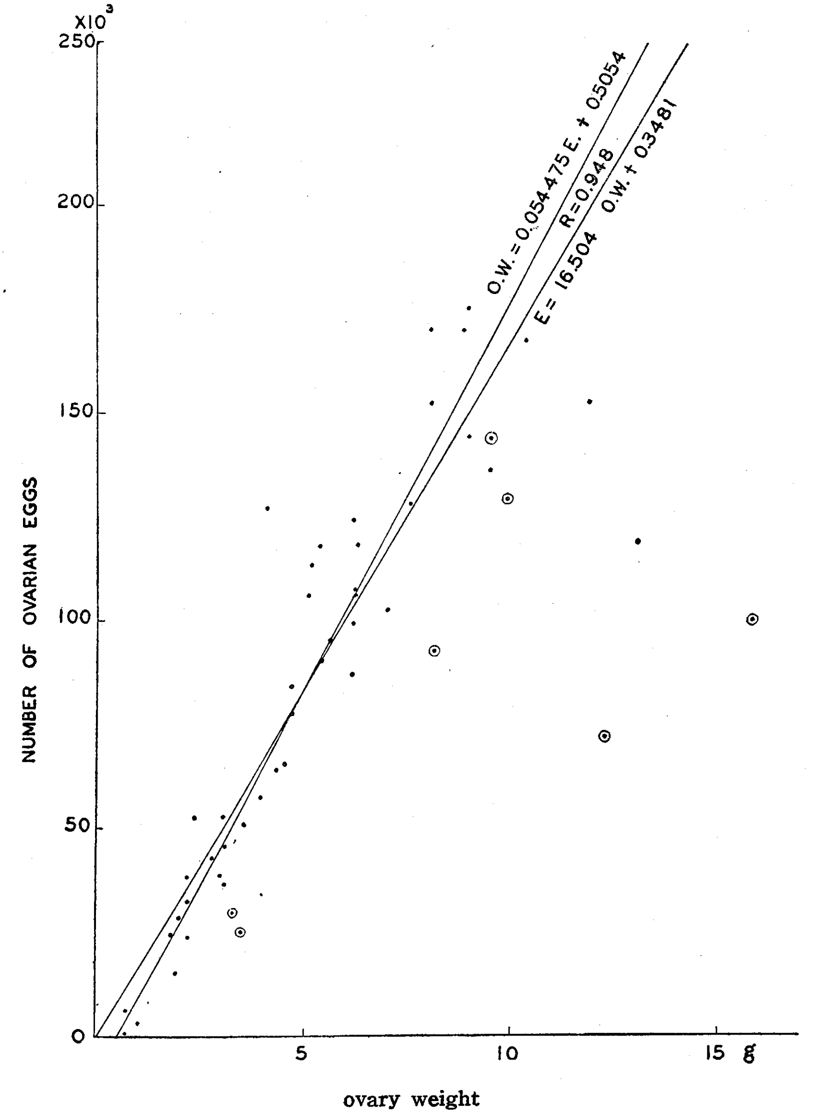

Fig. 5. Relation between the number of ovarian eggs (above 0.2 mm) and the ovary weight. ◉---------Ovaries containing transparent eggs are not included in the computation of regression, see text.

size, but not in number, as soon as the ovary begins maturation.

Estimation of the Amount of Eggs Spawned

The method generally in use for estimating the amount of eggs spawned is by subtracting the number of matured eggs of the post-spawning ovary from that of the pre-spawning ovary. This method is theoretically sound, because as stated above, the eggs measuring 0.2 mm in diameter increase only in size, but not in number, as the ovary begins maturation. In practice, however, it is difficult to identify with certainty the pre-spawning ovary from the post-spawning one. Following are two other alternatives that seem satisfactory for estimating the amount of eggs spawned.

As mentioned above, *A. macrocephalus* spawns during June-August. It was considered that less error would be encoutered, if by gross observation pre-spawning ovaries were selected early in the spawning season, and post-spawning ovaries selected later in the season. Accordingly, the pre-spawning specimens were collected during June-August, and the post-spawning ones during August-September, and the number of ovarian eggs larger than 0.2 mm in diameter was counted. The counted number of eggs was then plotted against the standard length as indicated in Fig. 6. The regression equations for the number of eggs (E) on the standard length (L_S) of both pre-spawning and post-spawning ovaries have been found to be:

$E=2.12067\ L_S-271.6645$ (*1*) pre-spawning

$E=1.50907\ L_S-200.6678$ (*2*) post-spawning

Subtract equation (*2*) from equation (*1*) and a general regression equation for the number of eggs spawned (ES) on the standard length will be obtained:

$ES=0.61160\ L_S-70.9967$

Another approach is to use the ovaries collected in June as pre-spawning specimens, and those in September as post-spawning specimens, and to compute the number of eggs spawned by indirectly employing the previously established relationship between the number of eggs and the weight of the ovary:

$E=16.504\ OW-0.3487$ (*1*)

The regression equations for the weight of ovary (OW) on the standard length (L_S) in June and Septembr respectively have been found to be:

$OW=0.12010\ L_S-16.39277$ (*2*)
June, pre-spawning
$OW=0.08112\ L_S-11.90376$ (*3*)
September, post-spawning

If equation (*3*) is subtracted from equation (*2*), a regression equation for OW on L_S between pre-spawning and post-spawning stages will be:

$OW=0.03898\ L_S-4.48901$ (*4*)

Again substitute the values in equation (*4*) for OW in equation (*1*), then a general regression equation for the eggs spawned (ES) on the standard length is derived:

$ES=0.64333\ L_S-74.0866$

The two methods give comparable results. The first method is considered better because it is straight forward and simple. The second method involves too much extrapolation and deduction, and is liable to risk uncontrollable sampling errors, because the random specimens collected either in June or September might be in different stages of maturation.

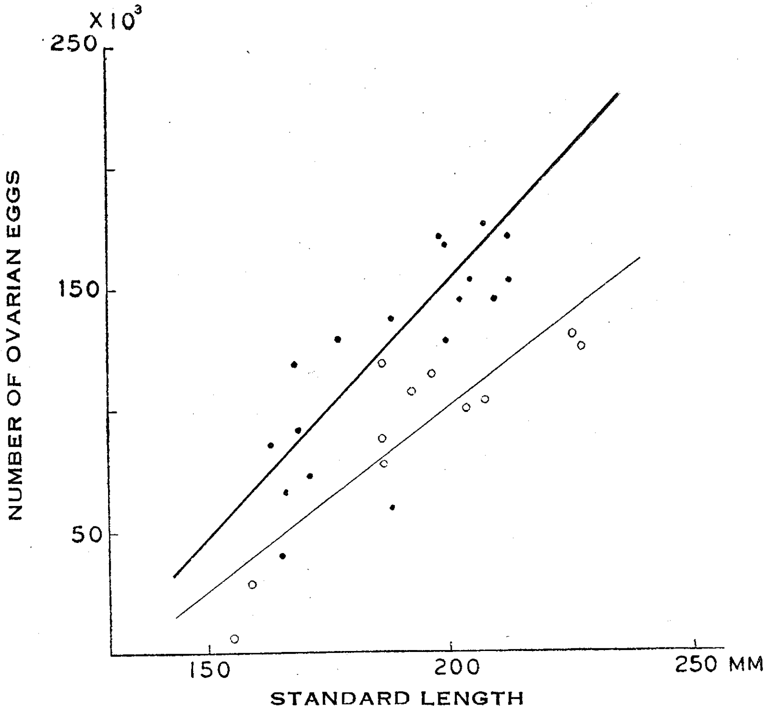

Fig. 6. Regressions of the number of ovarian eggs on standard length before and after spawning.

—— before spawning, $E=2.12067$ S. L. -271.6645
—— after spawning, $E=1.50907$ S. L. -200.6678

SUMMARY

Fishing data and fish specimens collected during June 1958-July 1959 were used to study the spawning and fecundity of *A. macrocephalus*. By analyzing the collective data of the gonadal conditions, maturation index and the development of the ovarian eggs, the spawning season of this fish is determined to be June-September, and the spawning ground is inferred to be along the sea coast of Fukien between Wenchow and Foochow. Simple mathematical equations have been established to estimate the egg-production potentialities of females and the amount of eggs spawned.

REFERENCES

1. a. DEPARTMENT OF AGRICULTURE and FORESTRY, TAIWAN PROVINCIAL GOVERNMENT. 1948-1953. *Ann. Rept. Taiwan Agr.* (In Chinese).
   b. Ibid. 1954-1960. *Ann. Rept. Taiwan Fish.* (In Chinese).
2. KASAHARA, H. 1948. Trawling fishery and natural resources in the East China and the Yellow Seas (In Japanese). *Research Rept. Japan Fishery, Inc.* No. 3, p. 27, 50-52; Figs. 14, 33.
3. SAISHU K., K. NAKASHIMA, and K. KOJIMA. 1954. On the reproduction of the "Shiroguchi.' (*Nibea argentata*) in the East China and the Yellow Seas. *Bull. Seikai Regional Research Lab.*, Nagasaki, Japan No. 4, p. 1-34.
4. LIU, F. H., and I. H. TUNG. 1956. The distribution and fluctuation of 10 important demersal fishes of the Northern Trawling Ground of Taiwan. *Rept. Inst. Fish. Biol.* **1** (1): 1-12.
5. LIU, F. H., and I. H. TUNG. 1959. The distribution and fluctuation of some demersal fishes of Taiwan Straits. *Rept. Inst. Fish. Biol.* **1** (3): 16-23.